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TO ENHANCE THE CAPABILITY AND INCREASE THE PRODUCTIVITY 1/1
OF A GROUP WORKIN.. (U) PRINCETON UNIV NJ DEPT OF
MECHANICAL AND AEROSPACE ENGINEERIN.. S M BOGDONOFF

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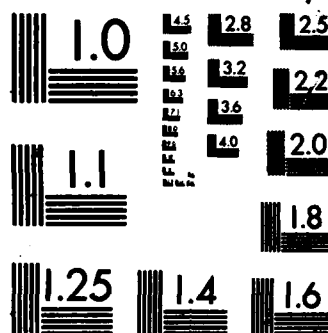
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**TO ENHANCE THE CAPABILITY AND INCREASE THE PRODUCTIVITY OF A GROUP
WORKING ON CRITICAL PROBLEMS OF HIGH SPEED FLUID MECHANICS -
BOTH EXPERIMENTALLY AND THROUGH NUMERICAL CALCULATIONS**

Seymour M. Bogdonoff

**Final Report
to the
Air Force Office of Scientific Research
DOD-University Research Instrumentation Program
GRANT AFOSR-83-0360
1 September 1983 through 31 March 1986**

**Report MAE-1753
May 22, 1987**

**PRINCETON UNIVERSITY
Mechanical & Aerospace Engineering Department
Gas Dynamics Laboratory
Princeton, NJ 08544**

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ABSTRACT

A new test channel has been designed and constructed to operate off the present high pressure air supply. The new facility is characterized by low turbulence, variable geometry (LTVG) supersonic operation (currently designed for Mach 3) at stagnation pressures from 50 to 150 psia. This facility provides a new and unique capability to study two- and three-dimensional supersonic turbulent boundary layers interacting with gradients and shock waves.

A new and enhanced data acquisition and processing system has been installed in the Laboratory. It is based on the DEC VAX-750 which provides multi-channel, high frequency, data acquisition and data processing capability for all of the Laboratory facilities.

INTRODUCTION AND RESEARCH OBJECTIVES

The original proposal for the 1983 DOD-University Research Instrumentation Program was submitted in November 1982. This proposal, entitled "To Enhance the Capability and Increase the Productivity of a Group Working on Critical Problems of High Speed Fluid Mechanics - Both Experimentally and Through Numerical Calculations," included four key elements:

- 1) The design and construction of two test channels to expand the capabilities of the existing supersonic high Reynolds number facility.
- 2) To enhance the available data acquisition/instrumentation installation.
- 3) To extend the laser fluorescence techniques to measurements in a complex turbulent flow.

4) To increase the capability of an existing computer to compute three-dimensional high speed flows.

This initial proposal totaled \$1,023,992. Approval was granted for the construction of one test channel at a total cost of \$312,800 and the enhanced data acquisition system at a cost of \$79,140.

The test channel, which was approved, was for the design and construction of a variable geometry supersonic low turbulence high Reynolds number channel (60-100 sq.in. test section) to permit the extension of research on three-dimensional shock wave boundary layer interactions to flows with much stronger shock waves and more extensive separation, and to investigate the effect of these interactions far downstream. The enhanced data acquisition/analysis capability was to expand the available data acquisition/analysis installation to increase the speed and capacity, to provide dual channels for multiple hot-wire and other high frequency instrumentation, and to interconnect the present and planned facilities.

Both of these objectives have been met. The funds allocated have been totally expended. The following sections detail both of these tasks.

TEST CHANNEL

The proposal for the new test channel was based on a preliminary design and estimates by University personnel and external contractors. With the program approval, detailed design of the test channel was undertaken. Professor S. M. Bogdonoff was responsible for the overall design and interactions with external sources of information and experience. Dr. Yiannis Andreopoulos was responsible for the preliminary design of the settling chamber section which was

designed in detail by Mr. Samuel Frendzel. Discussions, particularly regarding the throttling valve and settling chamber, were carried out with the Supersonic Tunnel Association, a group with wide experience in the design of supersonic facilities. Most important were the discussions with the NASA-Langley group headed by Ivan Beckwith. This group had, for some years, been working on the design of "quiet" wind tunnels. Mr. Robert Trimpi had made extensive studies and experiments on the design of a settling chamber for a new facility at NASA-Langley. Their information was particularly important in selecting the best possible throttling valve and settling chamber for this kind of facility. Once the preliminary concepts were determined, Andreopoulos and Frendzel concentrated on the details of the settling chamber. Professor Bogdonoff, with the staff of the Gas Dynamics Laboratory, Robert Bogart and William Stokes, carried the responsibility for the high pressure system and controls, the converging section, the supersonic nozzle and the diffuser sections. Most of the components were built in University facilities with external contractors used primarily for the "certified" high pressure welding.

A sketch of the final design is shown in Figs. 1a and b. The available high pressure air supply and distribution system was re-designed, Fig. 2, to provide a separate leg to the new facility, the LTVG test channel. The addition of cut-off valves will permit the new facility and the current operating facility to run independently but not concurrently. A key decision with regards to the regulator valve resulted in a decision to follow the NASA recommendation and use a special Fisher valve, Fisher Type 470-FBT-Whisper III-546. This regulator valve was followed by a diffuser equipped with rigi-mesh and screens to control turbulence and separation. The diffuser

started as a conical section (with a circular cross section) but was changed to an octagonal section at the diffuser outlet to ease problems downstream regarding the converging section. The diffuser was followed by a large octagonal settling chamber for turbulence and flow quality control, followed by an instrumentation section after the last screens. This section provides flexibility for future modifications as well as full access to the settling chamber for detailed measurements and characterization. Two converging sections were built - one to feed an 8" x 8" test section, the other to feed an 8" x 12" test section (needed to enhance the capability to carry out extensions of our 3-D studies). The octagonal initial section of the converging section changed to a rectangular section which matched the entrance to the two-dimensional nozzle blocks designed for a Mach number of 3. The throat of the supersonic nozzles are in the nozzle section, i.e. there is further 2-D convergence in the nozzle section. Although the nozzle contour has been held fixed for the present design (Mach number of 3), there are two nozzle configurations, both generating an 8" high test section. One generates a test section which is 8" wide, the other nozzle generates a test section which is 12" wide. The nozzle, in the usual configuration, has the 12" dimension in the horizontal plane, but the test channel can be rotated 90° to place the long dimension in a vertical plane when needed. The nozzles are made as a single 12" wide unit made up of two elements - a 4" and an 8" one. It is used as a single unit for the 12" configuration, and with the removal of the 4" section, can be used as the nozzle in the 8" configuration. The nozzle duplicates that in the high Reynolds number facility (8"x8") to provide the closest possible match to current operation of the high Reynolds number supersonic tunnel.

The test channel is designed to operate to 150 psia stagnation pressure. The settling chamber is provided with two large blow-out discs as a safety measure. The range of operation overlaps the low end of the high Reynolds number supersonic tunnel capability (60-150 psi at Mach number 3). No specific new test section has been designed or built. The present research contracts will use two- and three-dimensional test sections from the high Reynolds number supersonic facility for calibration and initial testing. Funds originally allocated for new test sections were re-allocated to cover construction and design over-runs. A major element for future test section design was accomplished by the acquisition of four 24" diameter windows from the dismantled MIT Supersonic Tunnel.

The diffuser is a very flexible design. It will accommodate 8" x 8" or 8" x 12" exits from the test section and will cover a flow path from axial (along the centerline of the settling chamber) to a maximum deflection of 30° at the test section. The diffuser is made up of multiple sections assembled as "building" blocks to match the test section designs. The diffuser exhausts into a current "exhaust and muffler" arrangement.

All of the test channel elements are essentially completed. The front end of the tunnel, high pressure feed regulator valve, settling chamber, converging sections, and nozzles, have been completed but there have been, thus far, no tests of the overall system. The current contract and air compressor plant limitations have delayed initial operation. The tunnel will probably operate late in the summer or in the fall of 1987, as manpower and air compressor plant capability will permit.

The test channel provides a new and unique capability not available in any other supersonic facility. The combination of a high Reynolds number range of over 2 to 1 at Mach number 3, an overlap with the high Reynolds number supersonic facility, low settling chamber turbulence level (which limits test section turbulence to the wall boundary layer inputs), capability to define settling chamber conditions and change them if desired, test sections of 8" x 8" and 8" x 12" which can be extended downstream in any desired direction (axial to 30° deflection) as far as the flow conditions can be maintained, provide a particularly flexible facility for future studies. Planned future research should provide unique measurements for two- and three-dimensional turbulent flows with gradients and shock waves.

ENHANCED DATA ACQUISITION/ANALYSIS CAPABILITY

Before the proposal was submitted in 1982, the Gas Dynamics Laboratory solicited proposals from several computer manufacturers to modify the available Hewlett-Packard 1000 unit which had been the base of Gas Dynamics operations for some years. The primary requirements were for multiple high frequency data acquisition channels and for increased speed and capability for analysis of data. On the basis of these studies, a bid from Hewlett-Packard and Preston for \$79,140 to modify and expand the available Hewlett-Packard 1000 system was the basis for the proposal. When the grant was finally received, Hewlett Packard and Preston declared that it was not possible to deliver the system detailed in the original bid. A whole new round of study, specification determination, and bidding was initiated. During the period between the original study for the proposal and the time of the grant, significant changes

in capability and structure of computers of the general class desired had taken place. There were important changes in the capability of the hardware and major changes in software, but the costs had also increased significantly. Of key importance was the shift from 16 bit to 32 bit machines. The final choice was a DEC VAX-750 and accessories which gave performance considerably above that originally specified and also had great potential for future expansion. The decision to buy the VAX computer system rather than the Hewlett-Packard expanded system was determined by the following considerations:

- 1) Princeton already had 17 VAX systems on campus, thus providing an opportunity to expand, maintain, and use existing programs already developed by other Princeton users,
- 2) The VAX machine was a 32 bit machine, as contrasted with Hewlett-Packard's 16 bit machine,
- 3) DEC was expanding its VAX line and maintaining complete upward capability of hardware and software. Hewlett-Packard had already announced they would no longer add products to their 16 bit series. Hewlett Packard did not have a 32 bit machine at the time.
- 4) The VAX system was supported by a wide range of third party vendors which made low cost peripherals more easily obtainable than that for Hewlett Packard.

Discussions between Princeton and AFOSR resulted in approval to buy whatever computer best met our needs, but with no additional funding. The system finally specified was the DEC VAX-750 and peripherals at a price of \$131,626. The University and the Mechanical and Aerospace Engineering Department supported the system by covering the difference between the new price and the

\$79,140 available from the original budget.

The University constructed a new computer room (cost about \$45,000) adjacent to the computer room which housed the HP-1000. When the VAX was delivered it was installed in the new room, put into operation, and checked out by DEC staff. During the phase-in program, the VAX systems were brought up while the Hewlett-Packard was still on-line to permit continuous operation of the many facilities in the Gas Dynamics Laboratory. The transition time took much longer than originally planned because of the incompatibility of Hewlett-Packard software and DEC software. When the transfer was finally completed, in 1986, the Hewlett-Packard machine was removed, and the old computer room was converted to a terminal room. During the past year, the computer has performed very well and has been used extensively in multi-channel high frequency data acquisition. The increased speed of the computer and space for additional terminals has had a very significant effect on the mode and level of operation, and has greatly extended our capability to do advanced research in the Laboratory.

CONCLUSION

The DOD-University Research Instrumentation Grant, AFOSR 83-0360, of \$391,940, has been expended in the design and construction of a new test channel with unique capability to study supersonic turbulent boundary layers and in a new and enhanced capability for data acquisition and analysis. These items have considerably expanded the capability of the Laboratory to carry out high speed research.

PUBLICATIONS

There were no formal publications. There will be a final report on the Low Turbulence Variable Geometry Supersonic Wind Tunnel when it is completely calibrated and its operational characteristics are fully determined. An informal presentation was made at the 66th Semi-Annual Meeting of the Supersonic Tunnel Association in October, 1986.

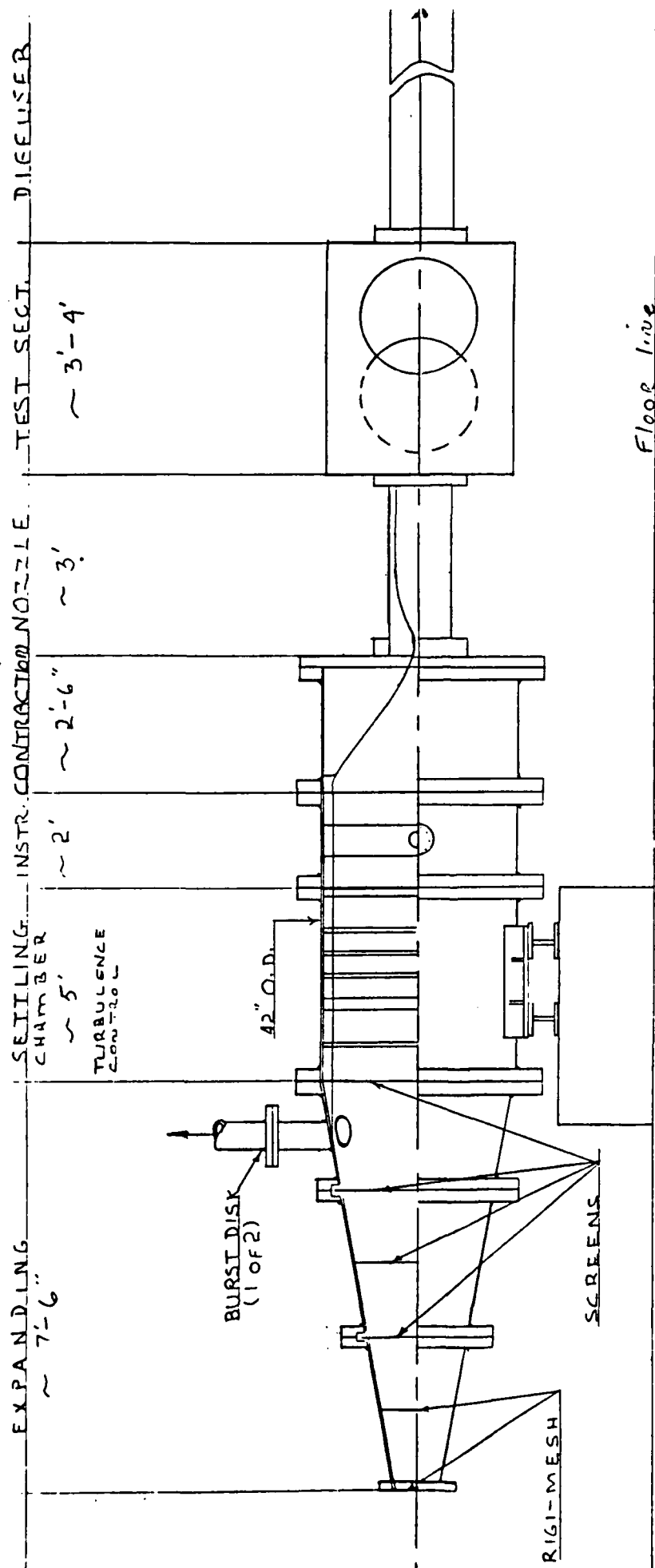


Fig. 1a. Horizontal view of tunnel assembly.

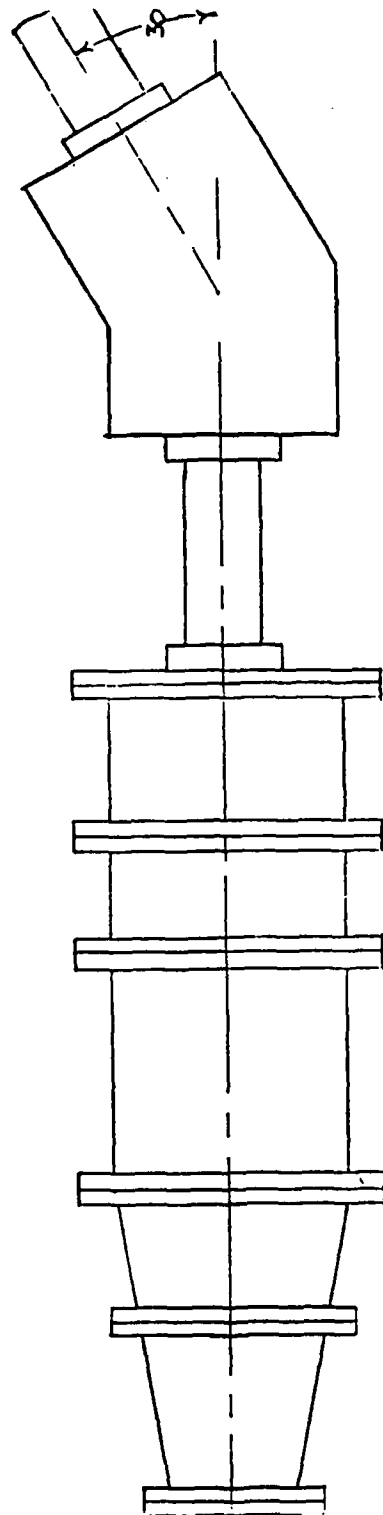


Fig. 1b. Vertical view of tunnel assembly with test section deflection of 30° .

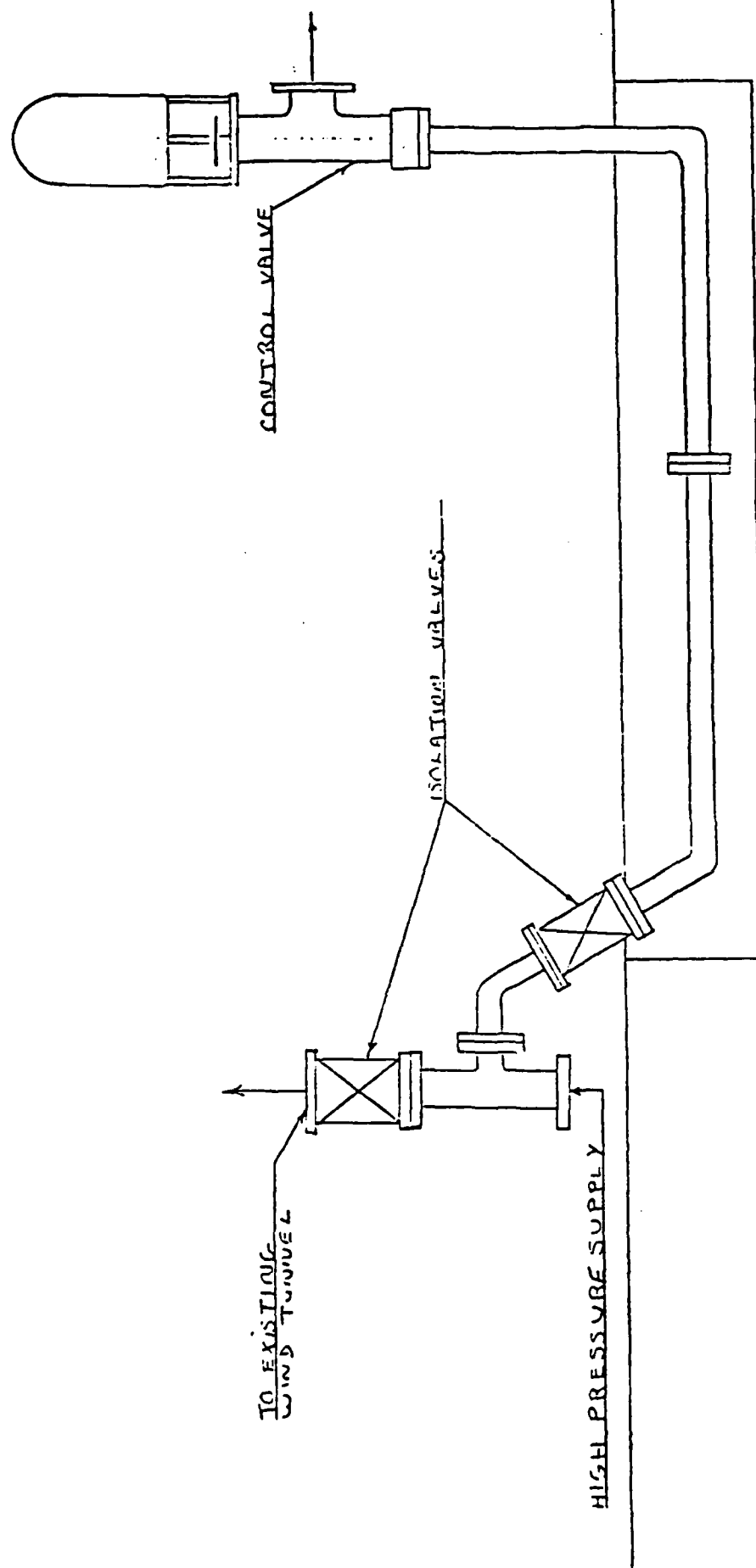


Fig. 2. Sketch of high pressure piping system.

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